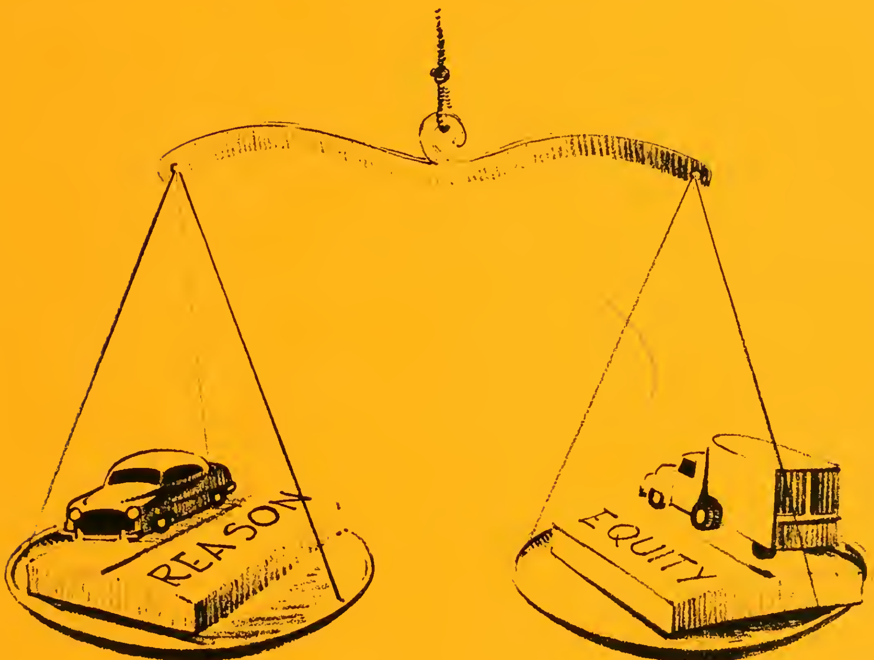
MONTANA FACT FINDING COMMITTEE
ON
HIGHWAYS, STREETS AND BRIDGES

A LAYMAN LOOKS AT



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INCREMENTAL ANALYSIS

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A Report Prepared

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For The

MONTANA FACT FINDING COMMITTEE

On

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In a nation where government is by the people, lawmakers cannot reasonably be expected to be expert in every field of scientific endeavor. Therefore, they must rely on consultation and advice from experts in the various governmental agencies committed to their charge. One of the main problems faced by any legislature is the equitable allotment of taxes amongst the recipients of the benefits the government provides. Unfortunately, the principles of taxation embrace many highly specialized arts and sciences. Although our legislators secure competent advice, lack of understanding of the fundamentals involved, because of the complexities of analysis, often prevents due consideration of a worthwhile basis for taxation.

The purpose of this short report is to set forth, in layman's language, a basis for taxing the motor vehicle users of our highways, which is considered by many experts in highway taxation and finance to have considerable merit It is the so called Incremental Solution, or Method of Differential Costs. The Montana Fact Finding Committee on Highways, Streets and Bridges has adapted the Incremental Solution to conditions peculiar to the State of Montana, to determine what fair share of highway costs should be borne by each class of highway user.

The fundamental concepts applied in the incremental solution are not difficult to understand, although the analysis itself is somewhat complex. It is this complexity which has led to some distrust in the method as a practical solution to the motor vehicle tax problem. However, other methods which are scientifically acceptable are equally complex, involve more definition, and produce results which are not so easily supported. Thus, there are analyses which seek to assign relative tax responsibility in proportion to operating costs, or to savings in operating costs that result from highway improvement. There are analyses which seek to define each element of highway construction and maintenance cost as a function of a vehicle type, making a proportionate assignment on this basis.

Contrasted against these complicated procedures for determining tax responsibility, there is one method which, because of its simplicity, has received wide acceptance and is commonly applied. This is the gross-ton-mile method. Most laymen find it easy to understand. It appears to be equitable since it takes into consideration the major factors known to influence road costs - weight and mileage. Basicly, each vehicle's loaded weight is multiplied by the mileage it travels to determine its relative responsibility for incurring road costs. Taxes are distributed in proportion to ton-miles of travel. The method is simple; the premises appear reasonable; however, the results are far from equitable. The main reason that the ton-mile theory does not produce a fair measure of responsibility is because it entirely disregards the road structure. It presumes that weight has the effect of requiring more costly highways, which is fairly obvious, but it makes no attempt to determine

the exact effect of weight. Engineers know that it is not so much the weight of a vehicle that influences road costs, but the manner in which weight is applied. For example, suppose that each of two vehicles of different types weigh 14 tons. One is a two-axle truck that transmits 18,000 pounds to the roadway by the rear axle, and 10,000 pounds to the roadway by the front axle. The other is a tractor-semitrailer combination with three axles. Its load is fairly well distributed, and it applies 11,000 pounds through the semi-trailer axle, 11,000 pounds through the rear tractor axle, and 6,000 pounds through the front axle. Since both vehicles weigh the same, they will be charged with responsibility at the same rate per mile of travel by the gross-ton-mile method, and yet the first vehicle has a far more damaging effect on the roadway than the second. Its 18,000 pound axle will require thicker and more costly pavement.

The incremental method attempts to make up for the deficiencies of the ton-mile method by measuring the effect of axle loads on the road-structure. The truck which imposes the 11,000 pound axle load should not have to pay for the additional pavement thickness that the truck imposing the 18,000 pound axle load requires. A passenger car, which imposes only a 2,000 pound axle load, should not have to pay for an element of structure required by trucks. Conversely, the vehicle imposing the 18,000 pound load requires not only its own <u>additional</u> thickness, or <u>increment</u>, but also all of the <u>initial</u> thickness that the passenger car uses. If we charge this truck with all of its own additional thickness, plus a fair share of the thicknesses used by the smaller vehicles, we have performed an incremental analysis. This is the essential requirement: that increases in costs be assigned to the vehicles incurring them, and that basic costs be assigned to all vehicles.

Not only do we deal with pavement or structural thickness in this manner, but also with other elements of highway cost. For example: a significant road test recently performed at Malad, Idaho, by the Western Association of Highway Officials, demonstrated that heavy vehicles require wider and stronger road shoulders than light vehicles. Shoulders hold roadway material in place under the paved travelling way and so prevent the pavement from breaking up. The 11,000 pound axle requires a certain width of shoulder; the 18,000 pound axle requires a wider shoulder. The cost of the <u>additional</u> width, or the <u>incremental</u> cost, should be borne by the vehicle with the 18,000 pound axle alone. The cost of the "basic" shoulder built for the vehicle with the 11,000 pound axle should be shared by both vehicles, since both require it.

It would appear from the foregoing that an incremental analysis must begin by subdividing the highway structure into elements of road cost, such as (1) right-of-way (2) grading and drainage (3) pavement surface and base (4) alignment an gradient, etc. Some of these elements would lend to an incremental distribution; others would not. No attempt would be made to distribute right-of-way incrementally, for example, since the amount of right-of-way required for a

highway is not influenced by the weight or size of vehicles using the structure. This is a basic facility required by all vehicles equally and may be fairly distributed by relative use of the highway, or in proportion to vehicle-mileage. Those elements which are assignable by weight would be broken into increments, each related to a given weight condition imposed on the road. Each increment would be charged to vehicles of such a weight as to require it. Perhaps we might start with a certain basic vehicle; for example a passenger car, and determine what structure would support it. This would be the first increment, or basic highway, whose cost should be shared by all vehicles, trucks included, because all vehicles require it. Then we might consider an additional thickness of structure, or width of shoulder, that trucks with a 2,000 pound to 5,000 pound axle load would require. All vehicles with more than 2,000 pound axle load would share the cost of this second increment, but passenger cars would not. Again, we might consider another addition to the structure, or third increment, that makes it capable of withstanding from 5,000 pounds to 10,000 pounds axle load. Vehicles with axle loading over 5,000 pounds would pay for it, not passenger cars or light trucks with less than 5,000 pounds axle load. The process may be continued to consider still larger axle load requirements. This is the way the incremental solution is usually developed; but, because so much separation of cost and definition of advantage is involved, Montana has sought a simpler solution, which will, at the same time, produce equally equitable results.

Although all of the illustrations used so far have considered only the magnitude of axle loading, it is not entirely the magnitude of an axle load that demands a better highway structure, but, rather, the number of repetitions that may be expected of a load of given magnitude. It is for this reason that we do not have to build all roads to the same standard. A secondary road that carries only a few maximum axle loads per day requires less thickness of structure than a primary road which carries many maximum axle loads per day. (This is fortunate, for, if it were not so, this State would be broke, and the taxes would be intolerable.)

At the same time we must build higher standards of roadway for volume of traffic alone regardless of axle load. Heavy trucks have an effect on this pure volume condition, or the capacity of any highway. Because of this interrelation of traffic volume, size, weight, and axle load, it is possible to pick from our different standards of highway a road that would fulfill all traffic requirements if vehicles of a certain related size were the heaviest vehicles using the highways. All additions to structure that we build on higher type roads are required either because of larger axle loads, or because of the hampering influence that heavy vehicles have on all traffic. The cost of these structural additions, if they may be so considered provide the basis for the Montana incremental solution. Engineering determinations have been applied in the detailed analysis to prove that the elements of additional structure which are developed from the foregoing consideration are fairly and

equitably distributed to heavy vehicles.

Another way of stating the same basic premise to the Montana method is that secondary roads are stages in the construction of primary highways. The development process whereby, historically, secondary roads are converted to primary highways, could stop with lower standards of road structure than we now find necessary, if there were no heavy trucks.

We make the following basic relationship. The standard of highway which has been designed in Montana to provide for traffic of from 200 to 400 vehicles per day would be entirely adequate for traffic of 4,000 vehicles per day <u>if trucks larger than 5 tons gross-vehicle-weight did not use the highways</u>. The structure of this roadway is entirely adequate for the 6,000 pound axle load that the 5 ton vehicle is capable of applying. Therefore, when we build a highway that will accommodate 4,000 vehicles per day of <u>all traffic</u>,all of the additional elements of structure we provide are required because of larger trucks and heavier axle loads.

Refer to the illustration setting forth the Montana solution in diagramatic form. The botton step represents the basic structure of any highway: that part of the roadway required by all vehicles. Whatever elements of construction are included are determined by elimination; it is the structure that is left over after all incremental assignments are made. The cost is charged to all vehicles on the same basis - proportional to the mileage each type travels on the highway.

The step which is second from the bottom represents an addition of paved structure that will withstand traffic of loaded 5-ton vehicles. It, together with the bottom step, provides the highest standard of highway we would have to build in the State (except where traffic volume requires four-lane facilities), if no trucks heavier than 5 tons were to use the highways. The axle load applied by the loaded 5-ton vehicle is 6,000 pounds, or 6 kips. A kip is an engineering term for 1,000 pounds, just as a ton is a common term for 2,000 pounds.

The next step represents an addition of paved structure that is necessary if this roadway is to withstand trucks larger than 5 tons, who might impose up to 10,000 pounds axle load.

The next step addition converts the roadway to withstand up to 14,000 pounds axle load; and the top step converts the roadway to withstand 18,000 pounds axle load.

Because of the interrelation of traffic volume and load, the two bottom steps, when built by themselves, will carry a volume of from 200-400 vehicles per day of <u>all traffic</u>, i. e. traffic which includes the heaviest trucks.

All five steps together, as shown on the right hand side of the stepped part of the diagram, represent the best two-lane highway we have to build for traffic up to 4,000 vehicles per day. It also represents half of a four-lane highway which is necessary for still larger volumes of traffic.

If there were no trucks larger than 5 tons, the bottom two steps would carry 4,000 vehicles per day - so that we build all in-between steps for trucks heavier than 5 tons. Each in-between step, together with all lower steps, represents a road that we will build on the State Highway system to carry a specified volume of all traffic. Each in-between step will carry a given axle load. Each would provide an adequate facility for 4,000 vehicles per day if trucks no larger than those related to the step were the heaviest on the highways.

We start with the step which is marked (4), second from the bottom. We then figure the additional cost per mile of highway for providing step (3). This cost for the number of miles of step (3) constructed is charged to all vehicles larger than 5 tons, or imposing more than 6,000 pounds axle load. We figure the additional cost of step (2), and charge the number of miles of step (2) to vehicles with more than 10,000 pounds axle load. Similarly, we charge the cost of step (1) to vehicles with more than 14,000 pounds axle load.

Once we have determined the cost per mile for providing steps (3), (2), and (1), we can plot a graph or curve of weight costs. We use this graph to determine a "weight" cost for step (4). This has the effect of separating another undefined increment which is not shown, and which will be charged to all vehicles larger than a passenger car. In other words, we have started with step (4) and have worked upwards establishing a trend in cost by weight. Now, we work downwards and carry the weight trend as far as it will logically apply.

When we have determined and distributed all of the increments of cost in any system of highways, and we handle each system separately, we are left with the cost of the basic roadway structure which all rehicles require. (This cost is obtained simply by subtracting the "weight" costs already assigned from the total cost of the system, which we know). This residual is then distributed to all vehicle types in proportion to the mileage they travel on the system.

To avoid confusion, the method of distributing the cost of each step above the basic highway has not yet been described. This distribution is made on the basis of 1000 pounds axle-mile use of the step.

While we have described essentially in terms of pavement structure, all of the differences of roadway are actually included in each step or increment.

We do not have to define these differences since they are all attributable to weight, of which axle load is a fair measure. We simply take the difference in cost of the steps as they will be built separately on different sections of the highway system. When the highway program is complete, a step will exist as a separate roadway of a given standard, or as part of the roadway that is built to a higher standard.

The solution is correlated with the Highway Needs Study now being conducted by the Montana Fact Finding Committee, Automotive Safety Foundation, consultants. The costs of the different steps will be determined by the Highway Department in the course of this study. In the incremental solution we are defining responsibility in terms of a complete highway product that will be adequate in twenty years. It is as if we took an apple, or any other whole and complete object, divided it into sections, and said that this part is the responsibility of such and such a person who must pay for it. This is another unique feature of the Montana solution - it does not matter when the highways are built since it is the complete product that is distributed.

What will result is a scale of responsibility - the figures are incidental. We can then apply that scale to any intermediate program of construction. The scale should be good for the twenty-year period.

This, in essence, is the incremental solution, as it will be applied in Montana. It provides a fair and scientific basis for taxation, since each vehicle's responsibility is related to the cost it incurs on the highways. It is especially noteworthy that the incremental method differs from the gross-ton-mile method in this respect.

In the brief outline presented in this pamphlet, much of the detail and argument contained in the larger work entitled "Incremental Method of Determining Motor Vehicle Tax Responsibility" is left out. The larger report presents the complete analysis, demonstrating that each portion of incremental cost is placed where it justly deserves to be. The relationship and handling of structures, maintenance, and administrative cost is described in detail. The effect of Federal Aid is discussed. A chart is produced to illustrate the distribution of incremental costs.

Consultation for the development of the Montana analysis was provided by an Incremental Advisory Committee composed of the following engineers: Mr. Scott P. Hart, State Highway Engineer; Mr. Mort Flint, District Engineer, Bureau of Public Roads; Dr. E. R. Dodge, Dean of Civil Engineering, Montana State College. The cooperation and advice received from this Committee has assured application of sound engineering principles to this incremental solution.

The methology of the Montana method has been discussed with interested persons, departments, and agencies, notably: the Committee on Highway Taxation and Finance of the Highway Research Board; the Financial and Administrative Branch of the Bureau of Public Roads; Mr. D. F. Pancoast, State of Ohio Department of Highways; representatives of the trucking industry; and the Oregon State Highway Department.

Initial response has been encouraging, and helpful comment and criticism have been received from these sources.

Copies of the larger report have been distributed to the Highway Research Board Committee; to the Western Highway Institute; to the National Highway User's Conference, Incorporated; to the Association of American Railroads; and to University of Washington engineers engaged in an incremental study for that State. Many of these agencies have promised written comment and suggestions.

This wide circulation of the Montana incremental analysis, and the solicitation of support, comment, and criticism at this time, is not without purpose. Your Committee is determined that the measure of tax responsibility produced will not be biased towards any user of the highways. Criticism and suggestions from experts, and from competing agencies will insure the fairness of the device.

Your support as laymen is desired. It is the purpose of this report to describe the underlying principles in terms that can be easily understood. Lack of understanding, and lack of appreciation of the availability of necessary information, has prevented general use of the incremental solution as a tax instrument, although experts have favoured the scientific reasonableness of the method for some time. Studies performed by The Planning Survey Division of the State Highway Department make available the characteristics of vehicular operation on our highways so that we do, in fact, have all the information necessary to apply the described incremental solution. The analysis will produce a fair measure of relative tax responsibility, and should be of considerable value to your legislature in setting up a tax structure.

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ON
HIGHWAYS, STREETS, AND BRIDGES

INCREMENTAL SOLUTION

DISTRIBUTION OF HIGHWAY COSTS TO MOTOR VEHICLE USERS
ON
PRIMARY AND INTERSTATE HIGHWAY SYSTEMS